Report as of FY2011 for 2010AZ412G: "Improving Hydrologic Investigations through Multi-Model Analysis and Discriminatory Data Collection "

Publications

Project 2010AZ412G has resulted in no reported publications as of FY2011.

Report Follows

Improving Hydrologic Investigations through Multi-Model Analysis and Discriminatory Data Collection

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Problem and Research Objectives

Practicing hydrogeologists are called upon to make specific predictions about future hydrologic conditions that will form the basis for social, economic, and political decisions. The major challenges to accurate hydrologic prediction are: 1) capturing the inherent complexity of hydrogeologic systems in models; and 2) acquiring sufficient informative data to characterize the critical hydrologic processes. Commonly, these modeling and measurement bottlenecks are seen as two interacting, yet separate, aspects of hydrologic science. We propose a novel approach that combines cutting edge tools in hydrologic modeling with a new approach to monitoring network design that addresses both of these fundamental limitations jointly. Specifically, ***we propose to test whether multi-model analysis combined with a discriminatory approach to data collection to design leads to the selection of more informative hydrogeologic measurement and monitoring networks***.

Our work on this topic has been divided into two phases. The objectives for Phase I are to develop a mathematical foundation for multi-model analysis and discriminatory data collection, and to asses this novel methodology on both synthetic test problems and data from previously published field experiments. The objectives for Phase II are to apply the methodology in Phase I to field studies in Arizona and Alaska. The field study in Arizona is a reanalysis of hydrologic monitoring data in the San Pedro River Basin, and the field study in Alaska is a hydrologic characterization study for West Twin Creek, a headwaters catchment underlain by discontinuous permafrost. To date, the work on Phase I is complete, and work on Phase II of the project will begin in June 2012.

Principal Findings and Significance

As part of the work in Phase I, computer code was developed to computer Data Discrimination Index values for potential observations, given a user-specified model ensemble. The relatively simple problem of one-dimensional transport of a conservative solute was selected to test the use of the Data Discrimination Index. From very early on in the study, it was clear that (a) it was possible to issue acceptable predictions of solute breakthrough with relatively few conditioning data, and (b) results were sensitive to the choice of likelihood-weighted model averaging technique used to predict solute concentrations. These results showed promise for our technique, subject to the limitations of likelihood-weighted model averaging.

The initial code was extended to benchmark measurement selection by the Data Discrimination Index against and exhaustive search of all possible solute concentration measurement sequences, to demonstrate that our method would identify globally optimal measurement sequences for providing information on model likelihoods. The results of this analysis indicate that solute breakthrough curve predictions conditioned upon a small, highly informative subset of concentration measurements - selected using the Data Discrimination Index - are equally accurate to those conditioned upon much larger datasets. One limitation of this method is that results are sensitive to the population of the model ensemble used to make predictions. Therefore, we also tested the performance of our method while drawing the true condition from different locations in the model parameter space. We found that the highly informative measurement sequences identified by the Data Discrimination Index were minimally affected by these variations, building confidence in our method.

To provide a more realistic test case for this method, we acquired data from a field-scale bromide transport experiment through unsaturated soils at the Etiwanda field site, California (Butters *et. al.*, 1989). We modified the existing code for compatibility with this dataset as the true condition from which concentration measurements were sampled. We formulated the measurement selection as follows: given a set of five measurements sequential time, to be performed at any depth, the goal is to predict attributes of the solute breakthrough curve at a target depth (3.05 m) beyond the range of available measurements. Predicted attributes included the peak concentration, peak arrival time, and exposure time (the length of time when solute concentration is above some threshold). We then repeated the same benchmarking procedure described above for this case. We found that solute breakthrough curves conditioned upon data from the first five depths were subject to greater error than the solute breakthrough curve conditioned upon data at the target depth. However, the small subset of measurements from the first five depths, selected using the Data Discrimination Index, led to predictions equally accurate to those conditioned upon a much larger measurement set. This is a similar result to that obtained using synthetic data.

The results of synthetic numerical experiments and post-audit analysis of the bromide transport field data were presented at the American Geophysical Union Fall 2011 meeting. We received substantial feedback which we have since incorporated into our code and analyses. We are finalizing a manuscript, to be submitted to the journal *Water Resources Research*, which describes this work. The computer code developed during Phase I of this project is modular and broadly suitable for use with problems different from the specific solute transport problem that we considered. Flexible computer code is essential for the field studies to be undertaken in Phase II of the project.

Work on Phase II of the project during summer 2012 will primarily be focused on the development of hydrologic conceptual models for the West Twin Creek catchment in interior Alaska. To date, a simple transient groundwater flow model has been developed for the West Twin Creek catchment, and accurately captures some features of streamflow hydrograph recorded at the catchment outlet. The suite of future conceptual models will likely include variable depth of the unfrozen soil active layer, and the use of conduit-flow equations commonly used in karst studies, but applicable to thermokarst and soil piping in permafrost-affected areas. Consideration of these hydrologic processes will likely improve model fit to existing data. Then, the procedure of computing DDI and identifying informative measurements will be applied using the code developed during phase I of the project. Potential informative measurements, if possible, will be incorporated into fieldwork at the site to be performed during late July and early August, 2012.

References

Butters, G.L., W.A. Jury, F.F. Ernst, Field Scale Transport of Bromide in an Unsaturated Soil, 1. Experimental Methodology and Results, *Water Resources Research* 25(7) 1575-1581, 1989.